Section 1 The Nature of Electromagnetic Waves

Objectives

After this lesson, students will be able to

O.3.1.1 State what an electromagnetic wave consists of.

O.3.1.2 Identify models that explain the behavior of electromagnetic waves.

Target Reading Skill

Outlining Explain that using an outline format helps students organize information by main topic, subtopic, and details.

Answers

Nature of Electromagnetic Waves

I. What is an electromagnetic wave?
   A. Producing electromagnetic waves
   B. Energy
   C. Speed
II. Models of electromagnetic waves
   A. Wave model of light
   B. Particle model of light

All in One Teaching Resources

- Transparency O28

Preteach

Build Background Knowledge L2

Radio Signals

Guide students in using what they already know about radio signals to infer how far radio waves can travel. Ask: **How far from home can you travel before you can no longer hear local radio stations?** *(Sample answer: Radio signals usually can be received many miles, and sometimes hundreds of miles, from their source.)* Tell students that radio signals are a type of wave, called *electromagnetic wave,* which they will read about in this section.

Section 1 The Nature of Electromagnetic Waves

Reading Preview

Key Concepts

- What does an electromagnetic wave consist of?
- What models explain the behavior of electromagnetic waves?

Key Terms

- electromagnetic wave
- electromagnetic radiation
- polarized light
- photoelectric effect
- photon

Target Reading Skill

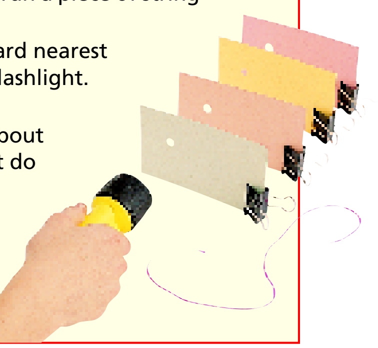
Outlining An outline shows the relationship between major ideas and supporting ideas. As you read, make an outline about electromagnetic waves. Use the red headings for the main topics and the blue headings for the subtopics.

The Nature of Electromagnetic Waves
I. What is an electromagnetic wave?
A. Producing electromagnetic waves
B.
C.
II. Models of electromagnetic waves
A.
B.

Lab zone Discover Activity

How Does a Beam of Light Travel?

1. Punch a hole (about 0.5 cm in diameter) through four large index cards.
2. Use binder clips or modeling clay to stand each card upright so that the long side of the index card is on the tabletop. Space the cards about 10 cm apart, as shown in the photo. To line the holes up in a straight line, run a piece of string through them and pull it tight.
3. Place a flashlight in front of the card nearest you. Shut off all light except the flashlight. What do you see on the wall?
4. Move one of the cards sideways about 3 cm and repeat Step 3. Now what do you see on the wall?



Think It Over

Inferring Explain what happened in Step 4. What does this activity tell you about the path of light?

Have you ever been caught in a rain shower? You run for cover until it passes, so you don't get wet. Believe it or not, you are being "showered" all the time, not by rain but by waves. You cannot see, feel, or hear most of these waves. But as you read this, you are surrounded by radio waves, infrared rays, visible light, ultraviolet rays, and maybe even tiny amounts of X-rays and gamma rays. They are all electromagnetic waves.

Electromagnetic waves ▶

Lab zone Discover Activity

Skills Focus Inferring

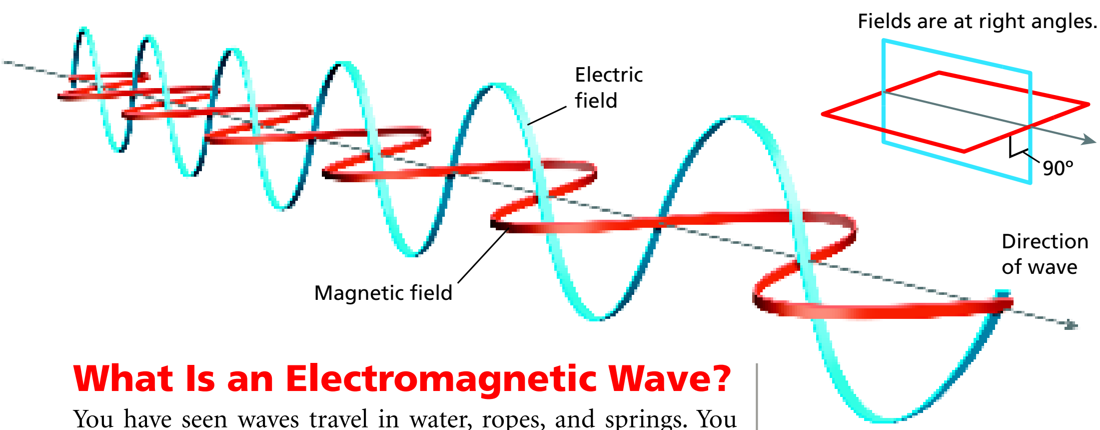
Materials 4 large index cards, hole punch, metric ruler, binder clips or modeling clay, string, flashlight

Time 10 minutes

Tip Use a small pocket flashlight or penlight for best results.

L1 **Expected Outcome** When the cards are positioned so that all the holes line up, the light from the flashlight is visible on the wall. When one card is moved out of alignment, the light is no longer visible.

Think It Over Moving the card in Step 4 blocked the path of the light. Students might infer that light travels in a straight line and cannot pass through a card.



What Is an Electromagnetic Wave?

You have seen waves travel in water, ropes, and springs. You have heard sound waves that travel through air and water. All these waves have two things in common—they transfer energy and they also require a medium through which to travel. But electromagnetic waves can transfer energy without a medium. An **electromagnetic wave** is a transverse wave that transfers electrical and magnetic energy. **An electromagnetic wave consists of vibrating electric and magnetic fields that move through space at the speed of light.**

Producing Electromagnetic Waves Light and all other electromagnetic waves are produced by charged particles. Every charged particle has an electric field surrounding it. The electric field produces electric forces that can push or pull on other charged particles.

When a charged particle moves, it produces a magnetic field. A magnetic field exerts magnetic forces that can act on certain materials. If you place a paper clip near a magnet, for example, the paper clip moves toward the magnet because of the magnetic field surrounding the magnet.

When a charged particle changes its motion, its magnetic field changes. The changing magnetic field causes the electric field to change. When one field vibrates, so does the other. In this way, the two fields constantly cause each other to change. The result is an electromagnetic wave, as shown in Figure 1. Notice that the two fields vibrate at right angles to each other.

Energy The energy that is transfered through space by electromagnetic waves is called **electromagnetic radiation.** Electromagnetic waves do not require a medium, so they can transfer energy through a vacuum, or empty space. This is why you can see the sun and stars—their light reaches Earth through the vacuum of space.

FIGURE 1
Electromagnetic Wave
In an electromagnetic wave, electric and magnetic fields vibrate at right angles to each other. **Classifying** *What type of wave is an electromagnetic wave?*

Go Online SCI LINKS NSTA
For: Links on the nature of waves
Visit: www.SciLinks.org
Web Code: scn-1531

Instruct

What Is an Electromagnetic Wave?

Teach Key Concepts L2

Electromagnetic Waves as Transverse Waves

Focus Read the boldface statement describing an electromagnetic wave.

Teach Call students' attention to Figure 1. Point out how the electric and magnetic fields in the figure are at right angles to one another. Ask: **What does the long arrow in the figure represent?** *(The direction of the wave)* **In what direction does the wave travel relative to the vibrations of the electric and magnetic fields?** *(The wave's direction is perpendicular to the vibrations of the fields.)*

Apply Have students answer the caption question. **learning modality: visual**

All in One Teaching Resources
- Transparency O29

Go Online SCI LINKS NSTA
For: Links on the nature of waves
Visit: www.SciLinks.org
Web Code: scn-1531
Download a worksheet that will guide students' review of Internet resources on the nature of waves.

Independent Practice L2

All in One Teaching Resources
- Guided Reading and Study Worksheet: *The Nature of Electromagnetic Waves*

Student Edition on Audio CD

Differentiated Instruction

English Learners/Beginning L1
Vocabulary: Word Analysis Write the word *electromagnetic*, and draw a line to separate the word into its two parts. Tell students that *electro-* means "electric." Relate *electric* and *magnetic* to familiar objects. Explain that both electric and magnetic energy are carried by electromagnetic waves. **learning modality: verbal**

English Learners/Intermediate L2
Comprehension: Ask Questions Check their comprehension by asking: **What is an electromagnetic wave?** *(A transverse wave that consists of vibrating electric and magnetic fields that move through space at the speed of light)* **What is electromagnetic radiation?** *(The energy that is transferred through space by electromagnetic waves)* **learning modality: verbal**

Monitor Progress L2

Drawing Ask students to draw a diagram showing how the electric and magnetic fields vibrate in an electromagnetic wave.

Answer
Figure 1 A transverse wave

Models of Electromagnetic Waves

Teach Key Concepts L2

Modeling Wave and Particle Behaviors

Focus Help students distinguish between the wave behavior and the particle behavior of electromagnetic waves.

Teach Explain that an electromagnetic wave vibrates back and forth like a transverse mechanical wave when it travels through space. However, when an electromagnetic wave strikes some substances, it acts like a stream of tiny particles of energy. Ask: **How could you model the wave behavior of an electromagnetic wave?** *(Sample answer: By making waves in a rope)* **How could you model the particle behavior of an electromagnetic wave?** *(Sample answer: By striking a surface with tiny particles, such as grains of sand)*

Apply Ask: **Which model helps explain how light can knock electrons out of some substances when it strikes them?** *(Particle model)* **learning modality: verbal**

Lab zone Build Inquiry L2

Observing How Filters Polarize Light

Materials flashlight, 2 polarizing light filters

Time 10 minutes

Focus Tell students that a polarizing filter transmits only light waves that are vibrating in a certain direction.

Teach Have students shine the flashlight through one of the polarizing filters. Ask: **Why does the light appear dimmer through the filter?** *(Only some of the light is transmitted.)* Have students experiment with placement of the second filter behind the first until they find an arrangement that blocks all the light. Ask: **Why are two filters needed to block all the light?** *(Sample answer: The first filter blocks all the light waves except those vibrating in one direction. The second filter is needed to block the remaining waves.)*

Apply Ask students to draw diagrams to show how light waves are affected by one polarizing filter alone and then by two polarizing filters together. **learning modality: kinesthetic**

Speed All electromagnetic waves travel at the same speed in a vacuum—about 300,000 kilometers per second. This speed is called the speed of light. At this speed, light from the sun takes about 8 minutes to travel the 150 million kilometers to Earth. When light waves travel through a medium such as air, they travel more slowly. But the speed of light waves in air is still about a million times faster than the speed of sound waves in air.

Reading Checkpoint What is the speed of light in a vacuum?

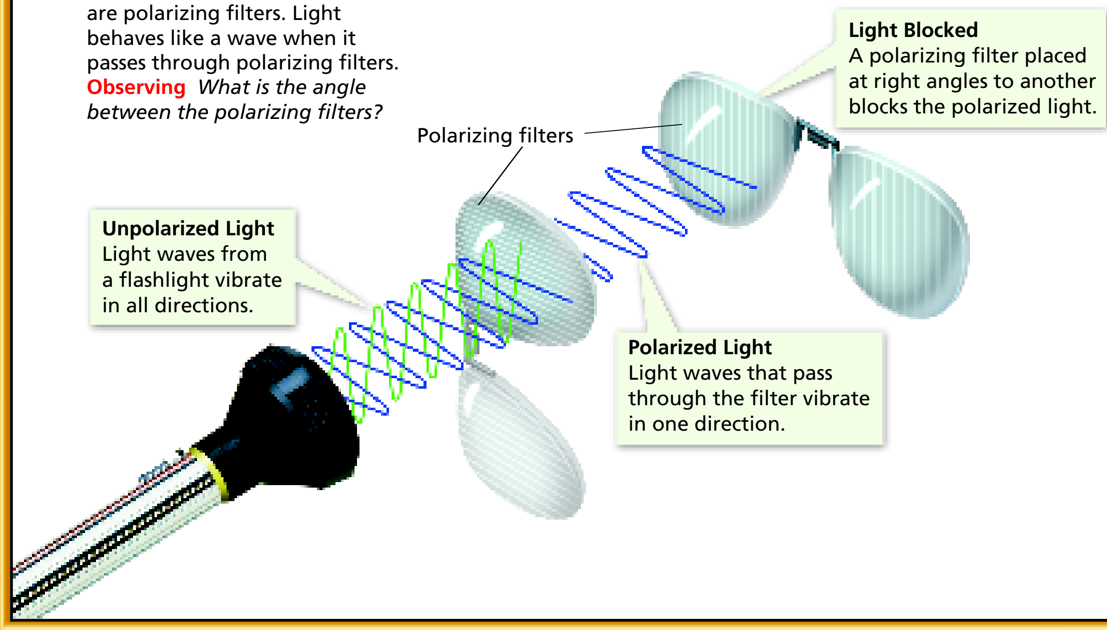
Models of Electromagnetic Waves

Many properties of electromagnetic waves can be explained by a wave model. However, some properties are best explained by a particle model. As you have learned, light is an electromagnetic wave. Both a wave model and a particle model are needed to explain all of the properties of light.

Wave Model of Light The lenses of many sunglasses, like the ones shown in Figure 2, are polarizing filters. Light acts as a wave when it passes through a polarizing filter. Ordinary light has waves that vibrate in all directions—up and down, left and right, and at all other angles. A polarizing filter acts as though it has tiny slits that are aligned in one direction.

Only some light waves pass through a polarizing filter. The light that passes through vibrates in only one direction and is called **polarized light.** No light passes through two polarizing filters that are placed at right angles to each other.

FIGURE 2
Light as a Wave
The lenses of some sunglasses are polarizing filters. Light behaves like a wave when it passes through polarizing filters.
Observing *What is the angle between the polarizing filters?*



Lab zone Try This Activity

Skills Focus Drawing conclusions L2

Materials 2 plastic cups, water, pan or sink, slide projector, slide, flashlight

Time 10 minutes

Expected Outcome The streams of water collide and splash into the sink, whereas the beams of light pass through each other without affecting the projected picture. This activity supports the wave model of light, because the water streams, which consist of particles, do not pass through each other without interference as light does.

Extend Ask: **How could a stream of water be used as a model for the particle behavior of light?** *(Sample answer: A stream of water strikes a surface as particles, the way light strikes some surfaces.)* **learning modality: kinesthetic**

To help you understand the wave model of light, think of waves of light as being like transverse waves on a rope. If you shake a rope through a fence with vertical slats, only waves that vibrate up and down will pass through. If you shake the rope side to side, the waves will be blocked. A polarizing filter acts like the slats in a fence. It allows only waves that vibrate in one direction to pass through.

Particle Model of Light Sometimes light behaves like a stream of particles. When a beam of light shines on some substances, it causes tiny particles called electrons to move. The movement of electrons causes an electric current to flow. Sometimes light can even cause an electron to move so much that it is knocked out of the substance. This is called the **photoelectric effect.** The photoelectric effect can be explained only by thinking of light as a stream of tiny packets, or particles, of energy. Each packet of light energy is called a **photon.** Albert Einstein first explained the science behind the photoelectric effect in 1905.

It may be difficult for you to picture light as being particles and waves at the same time. But both models are necessary to explain all the properties of light.

Reading Checkpoint **What is a photon?**

Lab zone Try This Activity

Waves or Particles?

1. Fill two plastic cups with water. Slowly pour the water from both cups into a sink so the streams of water cross. How do the two streams interfere with each other?
2. Darken a room. Use a slide projector to project a slide on a wall. Shine a flashlight beam across the projector's beam. What is the effect on the projected picture?

Drawing Conclusions Compare the interference of light beams with the interference of water streams. Does this activity support a wave model or a particle model of light? Explain.

Section 1 Assessment

Target Reading Skill **Outlining** Use the information in your outline about electromagnetic waves to help you answer the questions below.

Reviewing Key Concepts

1. a. **Defining** What is an electromagnetic wave?
   b. **Explaining** How do electromagnetic waves travel?
   c. **Comparing and Contrasting** What is an electric field? What is a magnetic field?
2. a. **Reviewing** What two models explain the properties of electromagnetic waves?
   b. **Describing** Use one of the models of light to describe what happens when light passes through a polarizing filter.
   c. **Relating Cause and Effect** Use one of the models of light to explain what causes the photoelectric effect.

Lab zone At-Home Activity

Polarized Sunglasses On a sunny day, go outside with your family members and compare your sunglasses. Do any have polarizing lenses? If so, which ones? Try rotating sunglasses as you look through them at surfaces that create glare, such as water or glass. Which sunglasses are best designed to reduce glare? **CAUTION:** *Do not look directly at the sun.*

Monitor Progress L2

Answers

Figure 2 The angle is 90°.

Reading Checkpoint 300,000 km/s

Reading Checkpoint A tiny packet of light energy

Assess

Reviewing Key Concepts

1. a. A transverse wave that transfers electrical and magnetic energy **b.** As vibrations in electric and magnetic fields that move through space at the speed of light **c.** An electric field surrounds every charged particle and produces electric forces that can push or pull on other charged particles. A magnetic field is produced when a charged particle moves, and it exerts magnetic forces that can act on certain materials.

2. a. The wave model and the particle model of light **b.** When light strikes a polarizing filter, only some waves pass through. These waves vibrate in only one direction and are called polarized light. **c.** When light acts like a stream of tiny particles of energy, called photons, the photons can cause electrons to be knocked out of some substances. This is the photoelectric effect.

Reteach L1

Read aloud sentences with a key term, substituting the word "*blank*" for the term. Ask students for the term.

Performance Assessment L2

Writing Have students write a paragraph describing how electromagnetic waves act like waves and how they act like particles.

Lab zone At-Home Activity

Polarized Sunglasses L1 Students will observe that polarizing lenses are better than regular sunglasses at reducing the glare from surfaces such as water or glass. When two polarized lenses overlap and one lens is rotated 90° relative to the other lens, no light shines through.

All in One Teaching Resources

- Section Summary: *The Nature of Electromagnetic Waves*
- Review and Reinforcement: *The Nature of Electromagnetic Waves*
- Enrich: *The Nature of Electromagnetic Waves*